ELECTRICAL MOISTURE METERS FOR WOOD

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"ELECTRICAL MOISTURE METERS FOR WOOD"

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INTRODUCTION

Measurements of the moisture content of wood are made in various ways. For scientific, experimental, and more or less basic measurements, moisture content values are obtained by the oven-drying method where the wood contains little or no volatile oil that would be given off when heated and be measured as water on a weight basis when present. Where volatile oils are present, either in the natural state or when added by impregnation, a distillation method is used in which the wood sample is placed in a liquid such as xylol or kerosene and heated. The moisture is distilled from the sample and collected in a measuring tube, the amount of water in which can be read from the scale as it separates out from the oil.

Electrical methods have come into extensive use in commercial control work in the manufacture of wood products and processing of lumber. They make use of such electrical properties of wood as its electrical resistance, dielectric constant, and radio-frequency power loss. Other methods not in common use consist of the measurement of relative humidities that develop in the air adjacent to a wood sample; and of a chemical reaction that removes water from the sample and produces a gas that causes a rise in pressure in an enclosure or a loss in weight of the wood by release of the gas. Paper treated with cobalt chloride indicates by its color the approximate relative-humidity conditions surrounding it.

Electrical moisture meters appeared on the American markets about 1930. They are designed to facilitate moisture content determinations for control purposes in the manufacture and processing of wood products. At least six manufacturers now make instruments that determine moisture content through its effect upon the direct-current electrical resistance of the wood and its effect upon the capacity and losses of a condenser in a high-frequency circuit when the wood serves as the dielectric material of the condenser. Instruments now on the market are quite satisfactory for the purpose for which they were developed. One manufacturer has developed a machine for marking moving boards of irregular moisture content or removing them from production lines.

[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Electric moisture meters that use the relation between moisture content and resistance are called the resistance type; those that use the relation between moisture content and dielectric constant are known as the capacity type; and the meters using the relation between moisture content and radio-frequency power-loss are designated as the radio-frequency power-loss type.

Resistance-type Moisture Meter

Relation Between Moisture Content and Resistance

The direct-current electrical resistance of wood changes at a tremendous rate with changes in moisture content below the fiber-saturation point. With a change from fiber-saturation point to the oven-dry condition, which involves a drop in moisture content from about 30 to 0 percent of the weight of the wood, the resistance increases a millionfold. Throughout this range of moisture content values, a nearly linear reciprocal relationship exists between the logarithm of the electrical resistance and the moisture content. This relation, however, fails to hold for higher values of moisture content. From the fiber-saturation point to the complete filling of the coarser capillary structure, at which in some cases wood has more than 200 percent moisture content on the basis of oven-dry wood, the electrical resistance changes less than fiftyfold. Consequently, the evaluation of moisture content by means of a resistance measurement can be done with greater accuracy below the fiber-saturation point (about 30 percent) than above it. At very low values of moisture content (below about 5 percent), the resistance becomes so high that it is difficult to measure, and moisture meters are not generally calibrated for these low values. Values of 0.46 megohms at 25 percent moisture content and 22,400 megohms at 7 percent moisture content for Douglas-fir are typical of those below the fiber-saturation point. Resistances for other species for moisture content values from 7 to 25 percent are shown in table 1.

Electrodes

Wood acts as a resistance element in the electrical circuit of a moisture meter. This requires that contact be made to the wood at two points. The type of contacts and distance between them should be constant for purposes of comparison and calibration.

Generally, such contact is made by driving needle points into the wood. Two needles connected by a retaining bar serve for each contact. The bars are mounted on a block of good insulating material with a handle arranged for driving and withdrawing the needles easily. The points of each pair are usually mounted 1/2 inch apart on the retaining bar and about 1-1/4 inches between the pairs. The contact length is about 5/16 inch for lumber. Generally, the points are located so that current will flow parallel to the grain when a moisture content determination is being made.

contact with thin material, such as veneer, can be made by using many very short needles on each electrode and driving them into opposite sides. It may be made by clamping surface plates to opposite faces of veneer.

The current flowing between electrodes will follow the path of least resistance, which is also the path with the greatest amount of moisture.

A study of moisture distribution in boards and planks that are being dried has shown that, after the entire piece has been dried below the fiber-saturation point, the moisture content in a plane located at one-fifth of the thickness of the material from its surface is usually very near the average of the piece. When using a needle-point type of electrode in wood in which the moisture distribution is produced by drying, the moisture meter indicates the moisture content at or near the points of the needles, since the wood becomes a better conductor as its moisture content increases. Because of these facts, it is possible to drive electrodes to any depth, and to evaluate the moisture content at approximately that particular distance from the surface. This is of great importance in the treatment of timber with wood preservatives, in the use of heavy timbers for many structural purposes, and, in fact, wherever moisture content is a vital factor. Nails may be used for this purpose to advantage, in place of the regular electrodes. Two nails are sufficient but a correction of 1 percent moisture content should be added to the meter reading.

Range of Moisture Content Values

The range of most resistance-type moisture meters for lumber lies between 7 and 25 percent moisture content. One instrument covers the range from 4 to 120 percent. In the 7-25 percent moisture content range the accuracy of resistance-type instruments, when properly calibrated and used for testing material up to 1-1/2 inches thick, or on heavier material that is known to be of uniform moisture content, should be within $\pm$ 1 percent of moisture content in most cases. It is not to be expected that readings of moisture content above 25 percent will be as accurate as those in the lower range, nor do they ordinarily need to be. This type meter is shown in figure 1.

Capacity and Radio-frequency Power-loss Type of Moisture Meter

Moisture Content and Dielectric Properties of Wood

The dielectric properties of wood vary in proportion to the quantity of water held by the wood. The relation between moisture content and dielectric properties is known for some species, but the exact knowledge of this relation is not as important for the construction and operation of a moisture meter as the fact that moist wood placed against the plates of a condenser in a radio-frequency circuit will cause a measurable change of current in the circuit. The effect of moist wood upon a condenser depends upon the moisture content of the wood.

Principle and Operation of the Capacity or Radio-frequency Power-loss Type of Moisture Meter

Instruments made with the different names of capacity and radio-frequency power-loss moisture meters appear to operate on the same principle. Radio-frequency current is established in a vacuum-tube circuit. The radio-frequency current is applied to some form of a condenser, which is pressed against a wood surface. The dielectric properties of the wood cause a reaction which is indicated by a current meter. The meter has two scales, one calibrated to show moisture content of Douglas-fir and one having equally spaced graduations. The instruments are supplied with conversion tables for changing scale readings into moisture content for species other than Douglas-fir. While the condenser is held free in the air, the meter is made to indicate zero by adjusting a variable resistor. The condenser is then pressed into contact with the wood being tested. Moisture content is read either directly from the meter or with the aid of the conversion table.

Electrodes

Electrodes are the surface-contact type. They vary in design according to the material for which they are to be used.

Use on lumber.--Two different electrode arrangements are suitable for use on lumber. One consists of two insulated plates that are placed on opposite faces of the piece under test. In the other, contact is made with eight spring-cushioned 1/4-inch brass rods equally spaced on the circumference of a circle. The rod contactors are self-adjusting for small surface irregularities. This type meter is shown in figure 2. The electric field penetration is presumed to be about 3/4 inch deep.

Use on thin material.--A set of electrodes developed especially for veneer has several concentric coplanar rings. The electrical field is concentrated near the plane of the electrodes, and therefore is usable on thin material.

Range of Moisture Content Values

The range of capacity or power-loss types of moisture meters if from zero to about 25 percent moisture content.

Automatic Moisture Control

A new machine has recently appeared that is intended to be used for measuring the moisture content of moving lumber. It is designed to mark or reject lumber having an irregular moisture content or a moisture content improper for use. It is planned for use in sorting lumber on the dry chain or material approaching cutting tables or planers. It is not known at this time whether the machine is designed on the basis of electrical resistance, capacity or power-loss characteristics.

Accuracy of Measurements

The most important factors that affect the accuracy of moisture-meter determinations are (1) species, (2) specific gravity, (3) moisture distribution, (4) thickness of material, (5) temperature, (6) contact, (7) grain direction, (8) high relative humidities, (9) number of measurements, (10) the personal element.

Species.--At any given moisture content both the resistance and dielectric properties of wood depend upon the species. The apparent variation between species may be partly due to specific-gravity differences in the case of the capacity or radio-frequency power-loss meters and electrolytes in the case of resistance meters. Most moisture meters are calibrated to read directly for Douglas-fir. The true value for other common commercial species can be obtained by applying to the meter indication corrections from tables supplied with each instrument.

Specific gravity.--The indications of resistance-type moisture meters appear to be independent of specific gravity.

The indication of capacity or radio-frequency power loss meters are proportional to the specific gravity of wood as well as to its moisture content. Since all species contain a considerable range of specific gravities, it is probable that the instrument calibrations are for the average specific gravity of each species. Any moisture content determination, therefore, carries an error proportional to the difference between the specific gravity of the piece being tested and the value used for calibration. The effect of specific gravity may be caused by the fact that, at the same moisture content, wood of high specific gravity contains more moisture than wood of low specific gravity.

Moisture distribution.--Surface moisture due to rain, dew, or dense fog forms a layer with low resistance and very high dielectric constant and radio-frequency power absorption. Water pockets existing within the wood would have the same characteristics as a wet surface layer. These conditions would cause both types of meters to show a moisture content that would be much too high. Surface moisture should be permitted to evaporate before moisture content determinations are made. The presence of a water pocket would be detected if more than one position were checked for moisture content. The presence of a moisture distribution due to drying may cause errors, as noted previously.

Thickness of material.--Electrodes of the resistance-type meter for use with wood up to 1-1/2 inches thick have been described. If the 5/16-inch points are used in material thicker than 1-1/2 inches, the values obtained will be accurate only when the wood has a uniform moisture distribution. If a drying distribution exists, a wet core would not be indicated. It would be preferable to drive two nails to one-fifth the thickness of the wood and use them for electrodes. The value thus obtained would represent the average moisture content of the wood.

The circular arrangement of spring-cushioned rods and concentric-ring electrodes are available for thick and thin material, respectively. The rod electrodes are for lumber 1/2 inch or more in thickness. According to information furnished by the maker, the penetration is 3/4 inch to 1 inch. For

thicker material, the probability of error increases with the thickness. Concentric-ring electrodes are for material 1/8 to 1/2 inch thick. Penetration is 1/8 inch. The ring electrodes can also be used on sheets less than 1/8 inch thick when laid on a suitable backing, such as glass.

Temperature.--As the temperature of wood is increased, its resistance decreases, and vice versa. Most resistance-type instruments are calibrated at 70° F. and require a correction, which is approximately to subtract 1/2 percent for every 10° above 70° F. and to add 1/2 percent for each 10° below 70° F. This approximation is shown graphically in figure 3. It is assumed that temperature has a negligible effect upon the accuracy of capacity and radio-frequency power-loss meters, since the manufacturers do not furnish a correction for temperature.

Contact.--The needle contactors of resistance-type meters should be driven their full length into sound wood if possible. Surface-type electrodes should be pressed firmly into contact with the wood surface. If poor contact is made with any type of electrode, too low moisture content will be indicated.

Grain direction.-- Resistance measured across the grain is slightly greater than that measured along the grain. It is general practice to measure moisture content in terms of resistance in the grain direction. Instructions with each instrument indicate the proper placement of electrodes.

Both the rod and ring electrodes of capacity and radio-frequency power-loss meters have circular symmetry and therefore cannot be affected by grain direction provided all the electrode is covered by wood.

Electrolytes.--When wood is treated with salts for preservative or fire-retarding purposes the wood becomes more conductive and consequently may indicate a moisture content greater than the correct value. This is also true of some glue lines and errors may result from such measurements.

High relative humidities.--When resistance-type meters are used in wet weather, their surfaces may become damp and provide leakage paths with resistances comparable to those associated with low moisture content values, and thus preclude measurements at low moisture content.

The capacity and radio-frequency power-loss meters are not subject to error caused by surface films on the instruments, because effects of surface leakage are eliminated through the initial balance.

Number of measurements.--A single measurement should not be depended upon as the true moisture content value of a piece of lumber if more can be obtained. A representative moisture content value should be an average of at least three determinations whenever possible. This is especially true of a small number of pieces. If an operator is pushed for time, as might be the case when checking a kiln load as it is removed from a kiln, one measurement per board checked may suffice to obtain a good average for the load, provided that a sufficient number of boards are checked.

Personal element.--The accuracy of moisture-meter determinations often depends upon the care with which the instrument is used. Conditions that require measurements to be made rapidly may lead to inaccuracies due to incorrect balancing, reading, location of points, poor contact, neglect of temperature correction, and dependence upon a single measurement. As much care as possible should be exercised in all measurements to obtain reliable values.

Foreign Instruments

German and Swiss instruments were available before the war, but the American makes are generally more simple to operate and are the ones in common use in this country.

Maintenance

General Considerations

The maintenance of moisture meters consists largely of replacements of exhausted or broken components. Periodic inspections will minimize the probability of failure while in use. Inspection periods will depend upon the amount of use given an instrument.

Replacements

Portable moisture meters operate on self-contained dry batteries. When partially exhausted, the batteries need replacement. The need for replacement of batteries is indicated by either a low battery voltage measured with the switch on or by the inability of an operator to obtain a steady-state balance. The meter will show a constant drift toward zero.

Vacuum tubes last for many, perhaps several thousand, hours of service. They seldom require replacement.

The needle contacts of resistance-type meters become bent or broken in use. It is advisable to have a number of spare needles and a wrench in the moisture-meter case.

The need for replacement of batteries and contactor needles can be minimized by always placing the switch in the OFF position when the instrument is not in use, and by carefully driving and withdrawing the needles with as little bending as possible. Some moisture meters automatically turn off the switch when the instrument case is closed. Rough handling of the instrument should be avoided.

Use of Moisture Meters

The importance of following the instructions accompanying any moisture meter cannot be overstressed. Every instrument has a complete set of instructions that are different for each make and may vary between models bearing the same name. When instructions are followed carefully, the necessary corrections applied, and reasonable precautions taken, the accuracy of ± 1 percent of moisture content mentioned under Range of Moisture Content Values can be expected.

Although the accuracy of moisture meters can be ± 1 percent, they are not recommended as control instruments for kiln-drying schedules because inaccuracies due to causes mentioned under Accuracy of Measurements can occur very easily. The value of a kiln charge warrants the greater time required for the precision determination by oven-drying. The average moisture content of a kiln charge, however, can be determined by moisture meters at the time of unloading if a sufficient number of boards are checked. Moisture meters also provide a quick means for segregating lumber into moisture content ranges before kiln drying.

Makers and Dealers of Electrical Moisture Meters[1]

Makers and dealers	Trade name	Type
L. R. Bradley & Co. 25 W. 45th St. New York, N. Y.	Bradley Electronic Moisture Meter[2]	Resistance
Colloid Equipment Co., Inc. 50 Church St. New York, N. Y.	Delmhorst Moisture Detector	Resistance
Delmhorst Instrument Co. 117 Cornelia St. Boonton, N. J.	Delmhorst Moisture Detector	Resistance
Hart Moisture Gauges, Inc. 126 Liberty St. New York 6, N. Y.	Hart Moisture Gauge and Kaydel Moisture Meter	Resistance

[1]This list has been prepared for the information of correspondents. The inclusion of names in the list implies no endorsement by the Forest Products Laboratory as to quality of service or cost.

[2]This meter was designed especially for determining the moisture content of wood and plaster prior to painting.

Makers and dealers	Trade name	Type
Hart-Moisture-Meters 1948 Grand Central Terminal Bldg. New York 17, N. Y.	Hart Moisture Meter	Resistance
Industrial Instruments, Inc. 156 Culver Ave. Jersey City, N. J.	Megohm Bridge	Resistance
Laucks Sentry Products 4441 Stuart Bldg. Seattle 1, Wash.	Laucks-Sentry[3]	Not known
C. M. Lovsted & Co. 4000 Iowa & Marginal Way Seattle, Wash.	Tag-Heppenstall and Moisture Register	Resistance Radio-frequency power-loss
Measurements Corporation Boonton, N. J.	Delmhorst Moisture Detector	Resistance
Moisture Register Co. 1510 W. Chestnut St. Alhambra, Calif.	Moisture Register	Radio-frequency power-loss Resistance
Moore Dry Kiln Co. Jacksonville 1, Fla. also North Portland, Oreg.	Tag-Heppenstall Moisture Meter and Moisture Register	Resistance Radio-frequency power-loss
National Engineering Co. P.O. Box 1475 Indianapolis 6, Ind.	Tag-Heppenstall Moisture Meter and Moisture Register	Resistance Radio-frequency power-loss
Standard Dry Kiln Co. Indianapolis 6, Ind.	Moisture Register Tag-Heppenstall Moisture Meter	Radio-frequency power-loss Resistance
Tagliabue Instruments Division Weston Elctrical Instrument Corp. Newark 5, N. J.	Tag-Heppenstall Moisture Meter	Resistance
Thwing-Albert Instrument Co. Penn St. & Pulaski Ave. Philadelphia 44, Pa.	Thwing-Albert Electronic % Meter	Resistance

[3]An automatic machine for sorting moving lumber.

Makers and dealers	Trade name	Type
James Allen Tuck 132 Nassau St. New York 7, N. Y.	High Speed Production Type Moisture Meter	Capacity
George E. Zweifel 1123 NW. Gilson St. Portland, Oreg.	Moisture Register	Radio-frequency power-loss

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1937. 20. Electric moisture meters. South.Lbrman.154:(1937), 35, illus.
21. Electric moisture meters. South.Lbrman.154:(1937), 31, illus.
22. Electric moisture meters. South.Lbrman.154:(1937), 49, illus.
23. Miscellaneous commercial moisture meters. South. Lbrman.154:(1937), 39, illus.
24. Miscellaneous moisture meters. South.Lbrman. 154: (1937), 33, illus.
30. What's new in electric moisture meters. South. Lbrman. 155 (1937), 44, illus.

Table 7 .--The average electrical resistance along the grain in megohms, measured at 80° F. between two pairs of needle electrodes 1-1/4 inches apart and driven to a depth of 5/16-inch, of several species of wood at different values of moisture content.

Species of wood	Moisture content in per cent																		
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Conifers:																			
Cypress, southern	12,600	3,980	1,410	630	265	120	60	33	18.6	11.2	7.1	4.6	3.09	1.78	1.26	0.91	0.66	0.51	0.42
Douglas fir (coast region)	22,400	4,780	1,660	630	265	120	60	33	18.6	11.2	7.1	4.6	3.09	2.14	1.51	1.10	.79	.60	.46
Fir, California red	31,600	6,760	2,000	725	315	150	83	48	28.8	18.2	11.8	7.6	5.01	3.31	2.29	1.58	1.15	.83	.63
Fir, white	57,600	15,850	3,980	1,120	415	180	83	46	26.9	16.6	11.0	6.6	4.47	3.02	2.14	1.55	1.12	.86	.62
Hemlock, western	22,900	5,620	2,040	850	400	185	98	51	28.2	16.2	10.0	6.0	3.89	2.52	1.58	1.05	.72	.51	.37
Larch, western	39,800	11,200	3,980	1,445	560	250	120	63	33.9	19.9	12.3	7.6	5.02	3.39	2.29	1.62	1.20	.87	.66
Pine, longleaf	25,000	8,700	3,160	1,320	575	270	135	74	41.7	24.0	14.4	8.9	5.76	3.72	2.46	1.66	1.15	.79	.60
Pine, northern white	20,900	5,620	2,090	850	405	200	102	58	33.1	19.9	12.3	7.9	5.01	3.31	2.19	1.51	1.05	.74	.52
Pine, ponderosa	39,800	8,910	3,310	1,410	645	300	150	81	44.7	25.1	14.8	9.1	5.62	3.55	2.34	1.62	1.15	.87	.69
Pine, shortleaf	43,600	11,750	3,720	1,350	560	255	130	69	38.9	22.4	13.8	8.7	5.76	3.80	2.63	1.82	1.29	.93	.66
Pine, sugar	22,900	5,250	1,660	645	280	140	76	44	25.7	15.9	10.0	6.6	4.36	3.02	2.09	1.48	1.05	.75	.56
Redwood	22,400	4,680	1,550	615	250	100	45	22	12.6	7.2	4.7	3.2	2.29	1.74	1.32	1.05	.85	.71	.60
Spruce, Sitka	22,400	5,890	2,140	830	365	165	83	44	25.1	15.5	9.8	6.3	4.27	3.02	2.14	1.58	1.17	.91	.71
Hardwoods:																			
Ash, commercial white	12,000	2,190	690	250	105	55	28	14	8.3	5.0	3.2	2.0	1.32	.89	.63	.50	.44	.40	.40
Basswood	36,300	1,740	470	180	85	45	27	16	9.6	6.2	4.1	2.8	1.86	1.32	.93	.69	.51	.39	.31
Birch	87,000	19,950	4,470	1,290	470	200	96	53	30.2	18.2	11.5	7.6	5.13	3.55	2.51	1.78	1.32	.95	.70
Elm, American	18,200	2,000	350	110	45	20	12	7	3.9	2.3	1.5	1.0	.66	.48	.42	.40	.40	.40	.40
Gum, black[1]	31,700	12,600	5,020	1,820	725	275	120	58	27.6	13.0	6.9	3.7	2.19	1.38	.95	.63	.46	.33	.25
Gum, red	38,000	6,460	2,090	815	345	160	81	45	25.7	15.1	9.3	6.0	3.98	2.63	1.78	1.26	.87	.63	.46
Hickory, true		31,600	2,190	340	115	50	21	11	6.3	3.7	2.3	1.5	1.00	.71	.52	.44	.40	.40	.40
Khaya[2]	44,600	16,200	6,310	2,750	1,260	630	340	180	105.0	60.2	35.5	21.9	14.10	9.33	6.16	4.17	2.82	1.99	1.44
Magnolia	43,700	12,600	5,010	2,040	910	435	205	105	56.2	29.5	16.2	9.1	5.25	3.09	1.80	1.17	.74	.50	.32
Mahogany, American	20,900	6,760	2,290	670	380	180	85	43	22.4	12.3	7.2	4.4	2.69	1.66	1.07	.72	.49	.35	.26
Maple, sugar	72,400	13,800	3,160	690	250	105	53	29	16.6	10.2	6.8	4.5	3.16	2.24	1.62	1.23	.98	.75	.60
Oak, commercial red[1]	14,400	4,790	1,590	630	265	125	63	32	18.2	11.3	7.3	4.6	3.02	2.09	1.45	.95	.80	.63	.50
Oak, commercial white	17,400	3,550	1,100	415	170	80	42	22	12.6	7.2	4.3	2.7	1.70	1.15	.79	.60	.49	.44	.41
Poplar, yellow[1]	24,000	83 20	3,170	1,260	525	250	140	76	43.7	25.2	14.5	8.7	5.76	3.81	2.64	1.91	1.39	1.10	.85
Shorea[3]	2,890	690	220	80	35	15	9	5	2.8	1.7	1.1	.7	.45	.30	.21	.16	.12	.09	.07
Walnut, black	51,300	9,770	2,630	890	355	155	78	41	22.4	12.9	7.3	4.9	3.16	2.14	1.48	1.02	.72	.51	.38

[1]The values for this species were calculated from measurements on veneer.

[2]Known in the trade as "African mahogany."

[3]A Philippine hardwood, identified as tanguile or some similar species.

ZM21171F

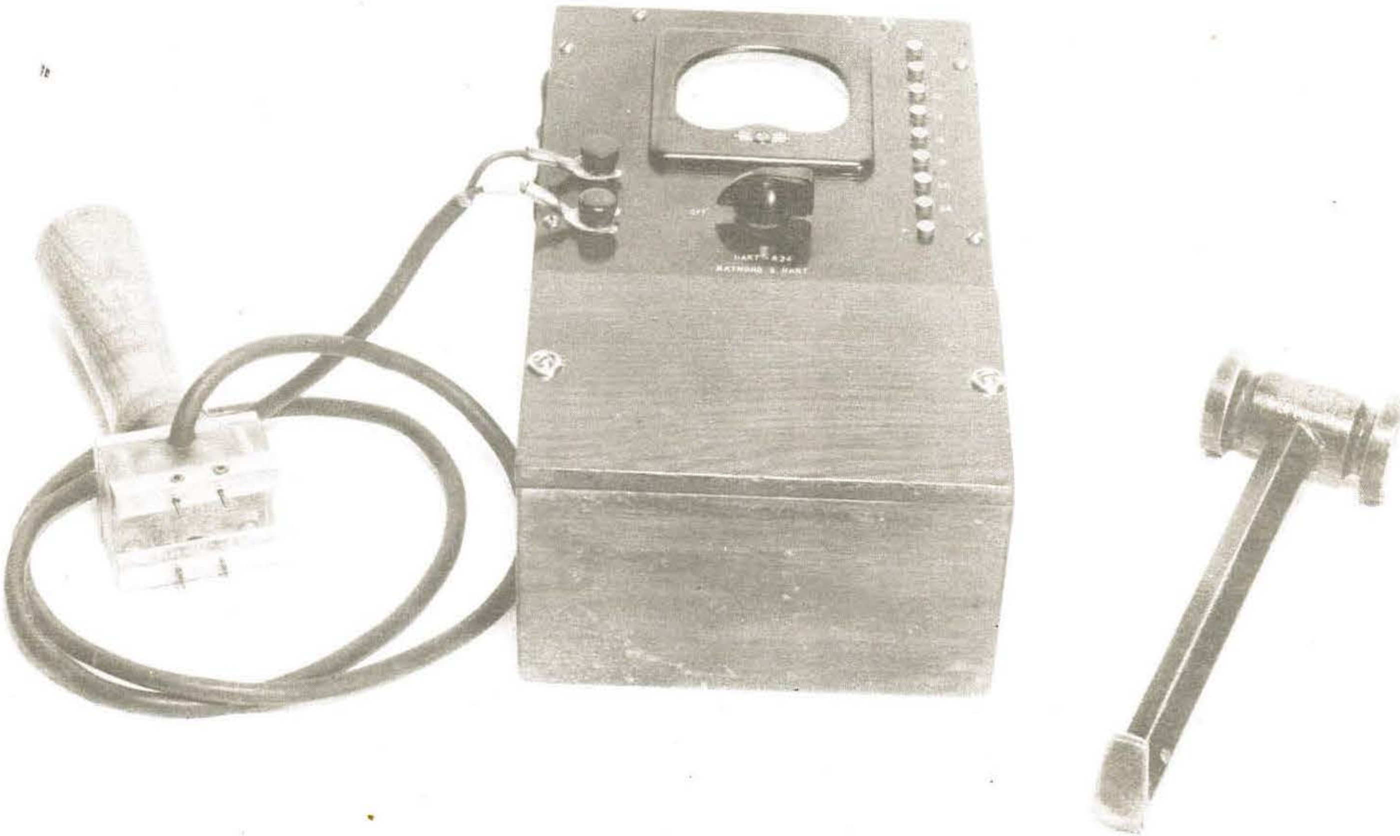

Figure 1.--Resistance-type moisture meter.

Z M 68017 F

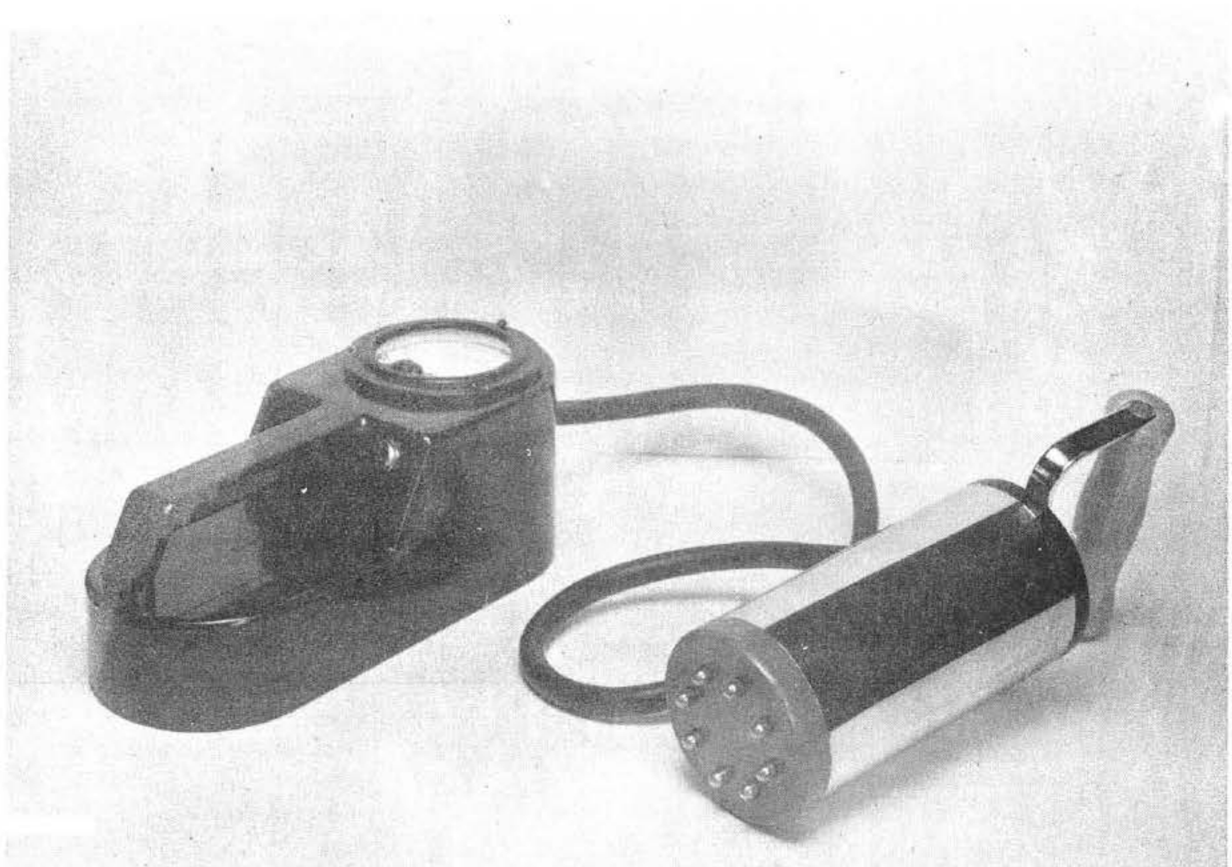

Figure 2.--Capacity or radio-frequency power-loss type moisture meter.

Z M 75142 F

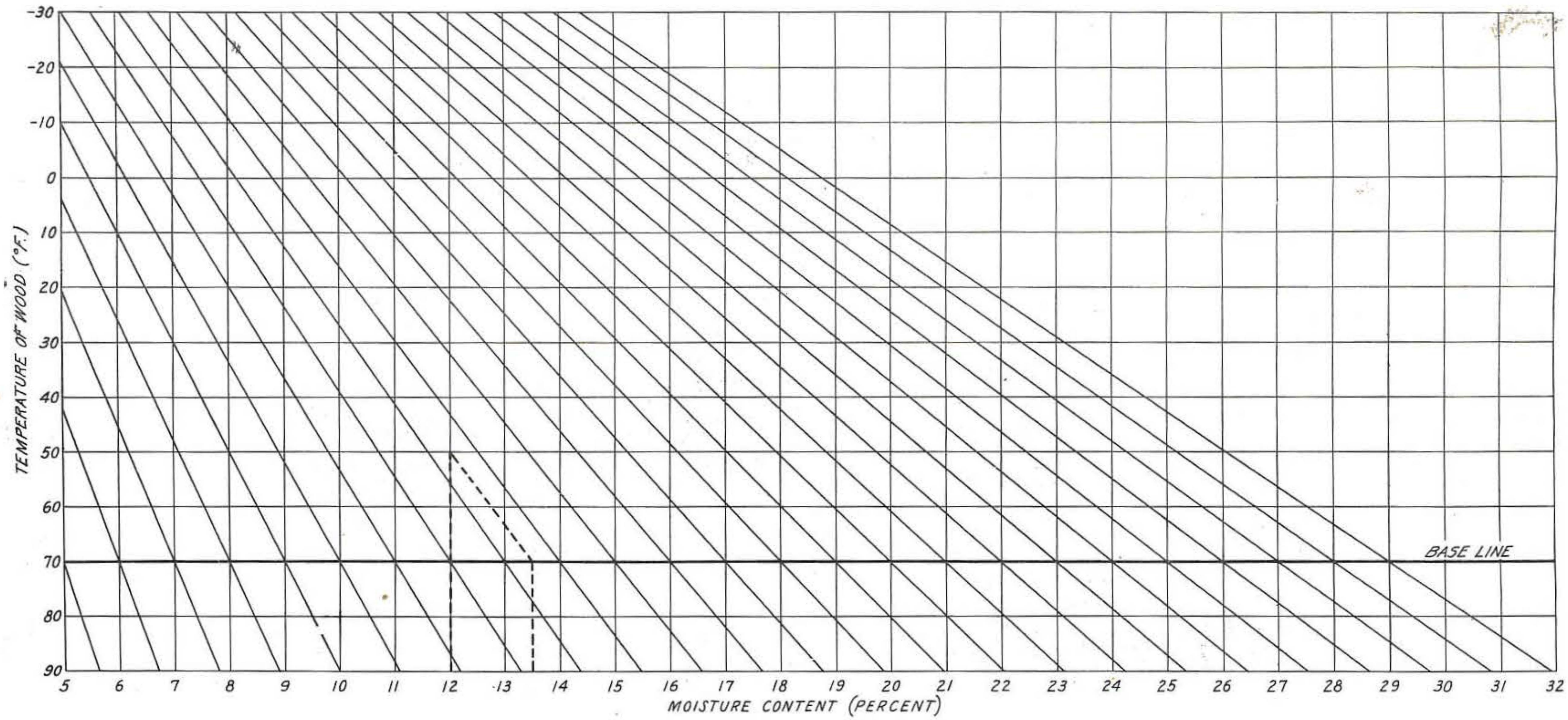

Figure 3.--Temperature corrections applicable to moisture content determined with electric moisture meters. Find the moisture content measured by the moisture meter on the lower margin of the diagram, follow this line vertically to the horizontal temperature line approximating the temperature of the wood being tested, then follow the sloping lines to the 70° F. base line and read the corrected moisture content vertically below. Example: measured moisture content, 12 percent, temperature of wood, 50° F., corrected moisture content, 13.5 percent.

Z M 76476 F